MODERN METHODS OF PROTECTION AGAINST LIGHTNING

ROY N. COVERT

FARMERS' BULLETIN 842

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Weather Bureau
C. F. MARVIN, Chief

Washington, D. C. Auust, 1917

Show this bulletin to a neighbor. Additional copies may be obtained free from the Division of Publications, United States Department of Agriculture

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1917

THIS bulletin will give those persons interested in protection against lightning concise, practical, and up-to-date information accompanied by specifications for installing the equipment so as to secure the greatest degree of protection with the type of installation chosen. It is not the purpose of this publication, however, to train those who study it to be lightning-rod experts and thus "eliminate the middle man," but rather to displace incorrect or vague ideas about lightning protection, so that one who proposes to have his buildings rodded may understand the requirements for such work, and be able to know when the work is well done and the cost reasonable.

The several sample sets of specifications, given herein, calling for rods and fittings of differing cost, will enable the prospective buyer of lightning protection to make an intelligent choice.

Even if one is expert at the mechanical work involved, and the job apparently is simple, it generally will be preferable to secure the services of a professional, unless possibly the "inexpensive equipment" of iron-pipe aerials, conductors, and grounds is excepted. To plan and execute properly an installation requires an accurate and experienced knowledge of the subject.

It is common for the lightning-rod agent to charge by the running foot of conductor for the whole equipment and its installation, including the ornaments if desired. It is believed, however, that it generally would be more satisfactory if the estimated price for protecting the building or buildings in question were itemized, and the cost of the conductor, the aerials, the grounds, the work of installing, etc., be given separately.

MODERN METHODS OF PROTECTION AGAINST LIGHTNING.

CONTENTS.

DESIRABILITY OF PROTECTION.

FOR OVER a century the scientific world generally has advocated the need of the protection of houses, barns, and other property against lightning, and experience has now proved conclusively that when the equipment to secure this protection is carefully and intelligently selected and installed the protection afforded is almost complete. In view of this experience many insurance companies make lower rates for protected buildings, while some companies will not insure an unprotected building at all. The Weather Bureau recommends the protection of all important farm buildings where thunderstorms are frequent, particularly when human or valuable animal life is involved. The best type of equipment should be used when practicable, although almost any kind of an installation is preferable to no protection at all. In fact no one should expose himself or his property to lightning, since good protection is available for a moderate outlay of money. The insurance company may reimburse the owner for the money value represented by a building that is destroyed by lightning, but the property is nevertheless destroyed and represents a waste, while life can not be restored. Moreover, a long period of time may elapse before a destroyed building can be replaced. The loss of a farm building will almost surely cause inconvenience and generally an actual money loss, even when the building is insured. Again, many persons experience an exaggerated fear during thunderstorms, and therefore greatly prefer to occupy a protected dwelling in which they feel and really are more secure. To such persons the avoidance of this intense discomfort, apart from the safeguarding of the property, fully justifies the installation of an adequate protective system.

The presence of a system of lightning conductors on a building serves in a small way to discharge the electricity silently during storms, and thus slightly to decrease the intensity and number of strokes of lightning. But there are times when the accumulation of atmospheric electricity is very rapid and the aerials and conductors on one building, or even on many buildings grouped together, are entirely insufficient to prevent strokes, as is obvious from the fact that trees are struck in the midst of forests. The points and conductors on buildings on such occasions merely serve to direct the stroke to the ground so that only a minimum of damage occurs.

It is sometimes stated that lightning conductors are undesirable because they "draw lightning." That may be true to a slight extent. A violent stroke of lightning that otherwise would come near to a conductor on a building would very likely be diverted to it and pass to ground harmlessly. On the other hand, if the building were unrodded, the stroke would probably cause damage; hence it is advisable to protect all buildings that are either valuable themselves or house valuable contents.

NATURE OF LIGHTNING.

The few remarks following give briefly the present-day concept of lightning:

The atmosphere and the earth's surface give evidence of electrification at all times; usually the potential of the atmosphere is positive with reference to the earth's surface. The process by which this electrification is produced will not be considered here. During thunderstorms, however, the electrification in the atmosphere, that is, the separation of the two kinds of electricity, is much increased, and the attraction of the two charges of opposite character or sign—usually positive electricity in the lower portions of the clouds and negative on the earth's surface, as also on the higher portions of the clouds—is also much increased. As a consequence, the electrical resistance of the intervening air may be overcome and a discharge occur; in which case there is a stroke or flash of lightning between cloud and earth, or between different parts of the cloud itself. It was generally considered formerly that lightning is an oscillatory discharge of electricity of great frequency, but many now regard it as essentially a one-way discharge. A somewhat better concept of a lightning discharge may perhaps be obtained by comparing it with the familiar electric light current. The voltage of a lightning discharge may be several millions as compared with the customary 110 of the electric light current; the number of amperes, or the current strength, may be in excess of 20,000 compared with only one or two passing through a high-powered incandescent lamp. But the duration of a lightning discharge is very brief, varying from a few

thousandths of a second to as much as half a second, so that a great amount of energy is dissipated in a very short interval of time.

The camera has shown that a lightning stroke often consists of several discharges following one another at brief intervals along nearly the same path; also that the path of such a discharge is shifted by the wind during the stroke. This shifting of the stroke is a factor to be considered in planning for lightning protection.

METHODS AND MATERIALS USED IN LIGHTNING PROTECTION.

KIND OF EQUIPMENT TO CHOOSE.

There are several factors that enter into a choice of the type of equipment, viz., the value of the building, the nature and value of its contents, whether the protection of human or animal life is involved, what sum of money is available for investment in protection, etc. In general a durable and adequate protection is best but the installation of such an equipment may be impracticable, or even uneconomical. As a rule, however, especially in regions of frequent and violent thunderstorms, dwellings, barns, and other buildings representing a considerable investment, or housing valuable or inflammable material, should be rodded in as effective and durable a manner as possible.

But there may be occasions when one's available funds will not permit an investment in expensive equipment. A less costly installation may then be made at some sacrifice of durability and efficiency, for a large measure of protection will still be assured. Moreover, because of their relatively small value many buildings do not require an expensive type of equipment. It should be remembered that such costly ornaments as glass balls, wind vanes, etc., do not add to the protection from lightning.

At times it may be impracticable, however, to install an equipment of even moderate cost. Under such circumstances a simple and inexpensive form of equipment may be used until it becomes possible to install one of the more desirable kinds.

With the object of meeting the various needs outlined above, three sets of specifications have been prepared for:

1. Copper-cable installation.
2. Installation of iron conductors and fittings.
3. Inexpensive equipment.

The copper-cable installation is considered to be the best, but it costs the most.

MATERIALS USED IN LIGHTNING PROTECTION.

The materials or fittings used in protecting a building from lighting may be classified under four heads: Conductors, fasteners for conductors, aerials, including points and supports, and grounds.

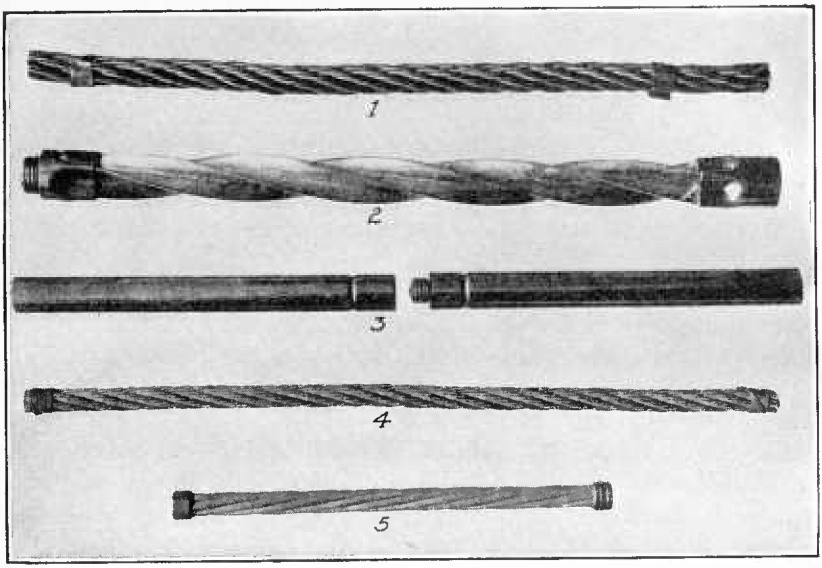

FIG. 1.—Lightning conductors. 1. Tightly twisted copper cable, ½ inch in diameter. 2. Galvanized star-section iron rod with copper couplings. 3. Copper tube, ⅝ inch in diameter; screw joints. 4. Galvanized-iron stranded cable, ⅜ inch in diameter. 5. Stranded cable, ⅜ inch in diameter; six iron wires and one copper wire in center.

At the outset it should be stated that to avoid electrolytic corrosion, the use of two different metals in the same system, such as copper and iron, should generally be avoided, particularly if moisture is continually present. Hence, if a copper conductor is installed, copper or gun metal fasteners and points should be used, not those made of iron or aluminum. Likewise a galvanized conductor should usually be accompanied by galvanized fittings. It is not always practicable or necessary, however, to adhere strictly to the rule of using one metal throughout the same system, but if two dissimilar metals are placed in contact their drying off quickly after rains or snows is essential to the prevention of corrosion.

Durability should be the principal factor determining the choice of the metal used. Such being the case, copper comes first, and iron next, the latter galvanized or copper plated. From the standpoint of first cost, iron has the advantage somewhat and is widely used for that reason, but it must be carefully protected from corrosion before being installed and continually watched to see that it does not deteriorate. Copper, however, resists corrosion almost indefinitely while exposed to the air, except about factories discharging vapors of nitric acid, or in soil relatively free from ammonia. Aluminum also is used for lightning protection, but rarely as compared with copper or iron, although it is almost equally as noncorrosive as copper except in the presence of alkalies. All the metals considered meet the require-

ments for strength and electrical conductivity, and therefore durability, as before stated, is the determining factor.

Conductors.—Several kinds of lightning conductors, readily available on the market, are illustrated in figure 1. For all practical purposes the tightly twisted copper and iron cables and the star-section iron rod are the best forms of conductors, the cable having the advantage somewhat because of its flexibility, which makes it easy to install. Moreover, the cable may be secured in lengths of several hundred feet; hence it can be installed with a minimum of joints. The iron rods are manufactured in lengths of 6 or 8 feet with screw joints of copper. Galvanized or copperplated (not copper "washed") iron rods should be used in preference to those formed by wrapping a covering of sheet copper about the galvanized iron. This latter construction is objectionable because of the possibility of galvanic corrosion that obviously may occur without its being observed, since the external appearance of the rod remains unchanged. However, if the iron rod is copperplated, there should be little trouble from corrosion, but such a treatment would seem to make it unnecessary to use a copper cover, which adds to the cost of the rod.

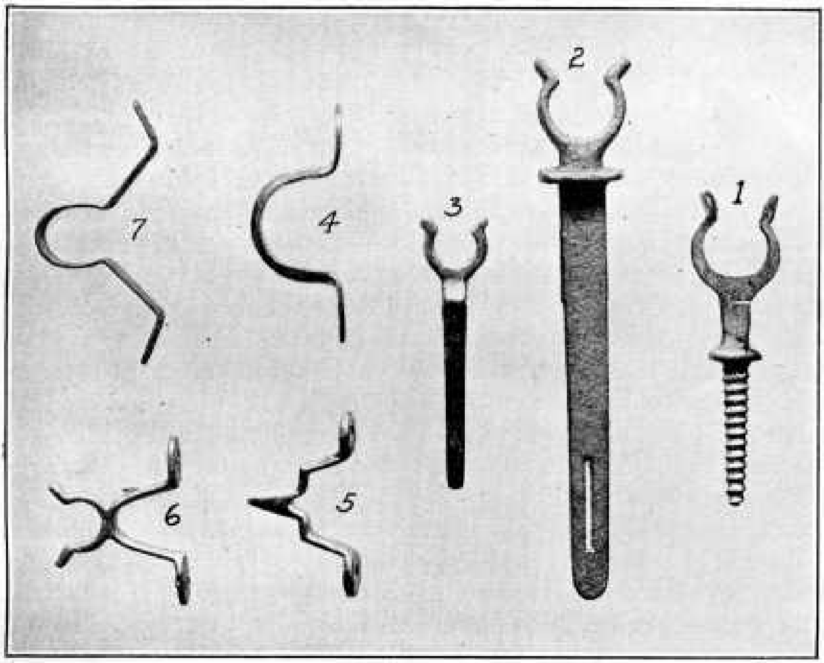

FIG. 2.—Fasteners for securing conductors to buildings. 1. One-piece screw fastener for cable or star-section rod. 2 and 3. Fasteners for use in brick, concrete, and tile walls while building is being constructed. 4. Clip or strap for pipe or rod conductors. 4. Fastener for star-section rod laid on surface of building. 6. "Disperser" attachment for cable. 7. Loop attachment for star-section rod.

Painting of conductors.—A galvanized or copperplated conductor should not be painted until corrosion makes it necessary. When freshly galvanized iron is painted, the paint tends to peel and crack, and in addition the zinc is liable to injury. Copper ordinarily does not require paint or plating, but copper aerials exposed to the acid gases from chimneys should be protected by being plated with lead.

Fasteners for conductors.—Several types of fasteners for securing the conductors to the building are illustrated in figure 2. The kind chosen for any particular installation depends largely upon the nature of the building, the construction of its roof and walls, the type of installation, and whether the fasteners are to be put in place when the building is being erected or attached to a building already finished. Nos. 1, 2, and 3 of the fasteners shown are among the most suitable. No. 1 is designed to be screwed into the building, or used with expansion sockets in masonry walls. Such fasteners are not easily loosened after being screwed into place, are strong and not subject to corrosion, and are so made as to permit the cable to move slightly when expansion and contraction occur because of temperature changes. If the cable were rigidly secured to the fastener, its movement would tend to loosen the fastener. The above-mentioned fasteners are also desirable because they space the conductor away from the building a short distance, and thus prevent the accumulation of dirt with moisture between the conductor and the building, but on the other hand the spacing should not be too great. Ice accumulating between the rod and the building has been known to loosen the fasteners.

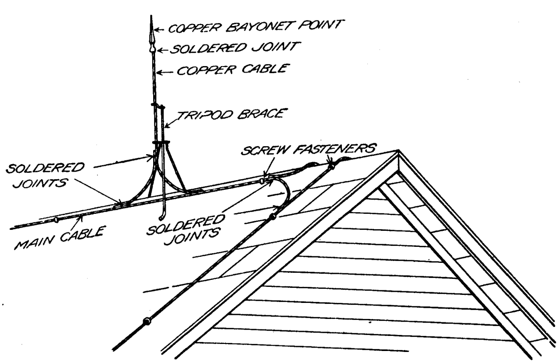

FIG. 3.—Tripod support for copper-cable aerial.

Plumber's clips, and the other simple forms of fasteners illustrated, are suitable only for inexpensive or temporary installations.

Aerials; points and supports.—Aerials are used in lightning-protection systems partly to direct a stroke of lightning, and they also prevent strokes to some slight extent by silently discharging the static electricity of the atmosphere over a building. Obviously, if they are imperfectly erected and liable to be thrown down by high winds, they are worse than useless. An aerial with a tripod support is illustrated in figure 3, which, if carefully installed, should be secure against damage from wind and the snow and

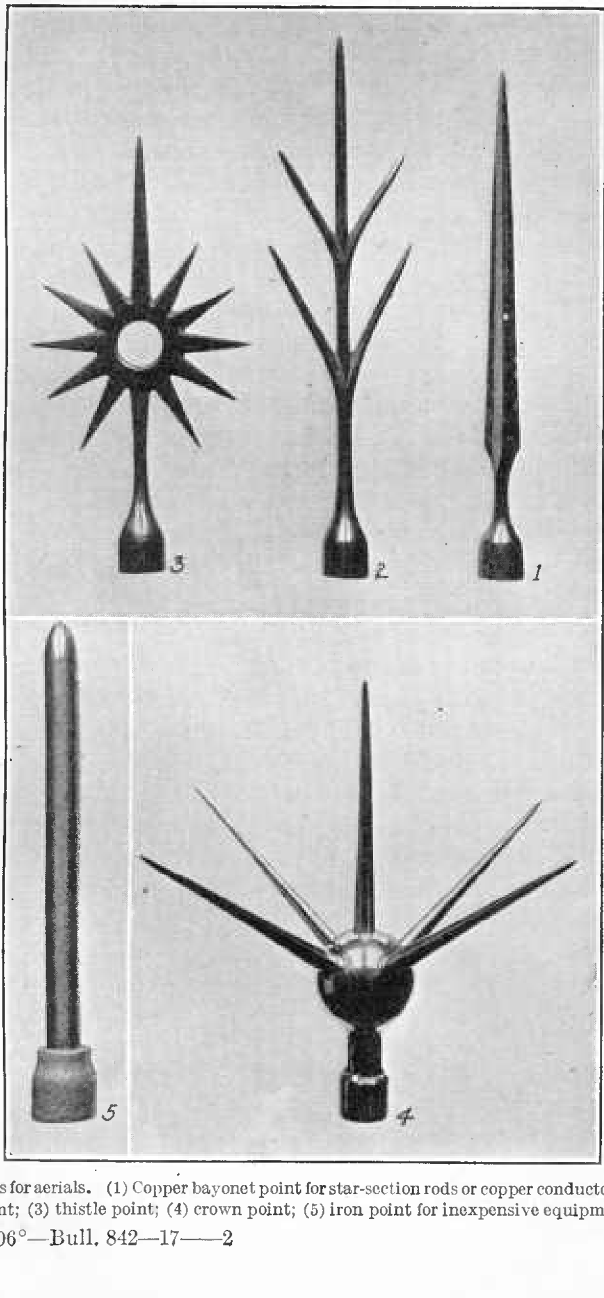

FIG. 4.—Points for aerials. (1) Copper bayonet point for star-section rods or copper conductors; (2) sprangle point; (3) thistle point; (4) crown point; (5) iron point for inexpensive equipment.

ice storms of winter. This support is constructed of galvanized iron, the vertical portion being designed to support the conductor with the attached point at two places. The three legs are usually held down by screws to the portion of the building on which the aerial is erected. These supports could be copperplated for use with copper-cable conductors.

Several types of points for aerials are pictured in figure 4, some having single and others multiple points. Generally, however, there is little choice between single and multiple points, provided they fuse with difficulty and are strong and durable. One large-sized, substantial, solid point would be less likely to be fused by a stroke of lightning than several small-sized multiple points, one or two of which would probably take most of the discharge. Tubular points as purchased on the market do not as a rule have sufficient metal in them to conduct a heavy discharge of lightning and are likely to be fused. Copper or iron points are preferable to aluminum, because they fuse less readily. The plating of the points does not add to their usefulness, unless it prevents corrosion. Tipping the points with a metal that fuses at high temperature, such as platinum, does not serve a useful purpose; it merely adds to the cost.

Grounds.—The materials entering into the construction of grounds are discussed below under "Methods followed in installing equipment."

METHODS FOLLOWED IN INSTALLING EQUIPMENT.

When one has concluded to protect his dwelling or barns against lightning, the next question to answer is: How shall the work be done? Almost always it will be necessary to call upon an expert to plan and install the equipment and to furnish the materials needed, but the methods to be followed should be common knowledge and well understood in advance by the prospective purchaser. If the installation is to be an extensive one, however, it would be advisable to secure competition, and submit brief, general specifications to

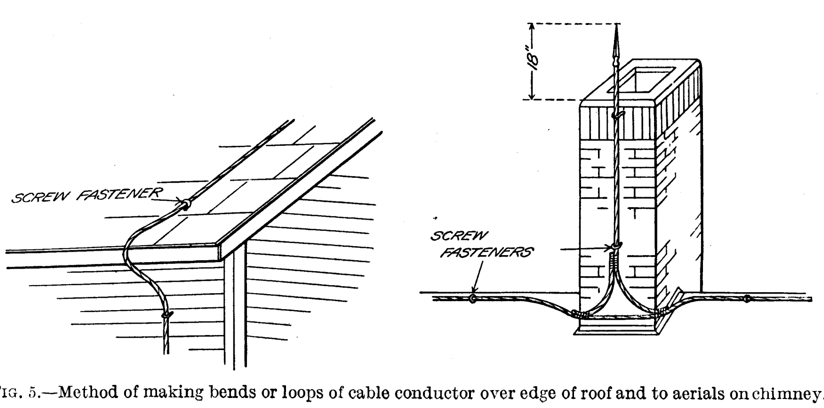

FIG. 5.—Method of making bends or loops of cable conductor over edge of roof and to aerials on chimney.

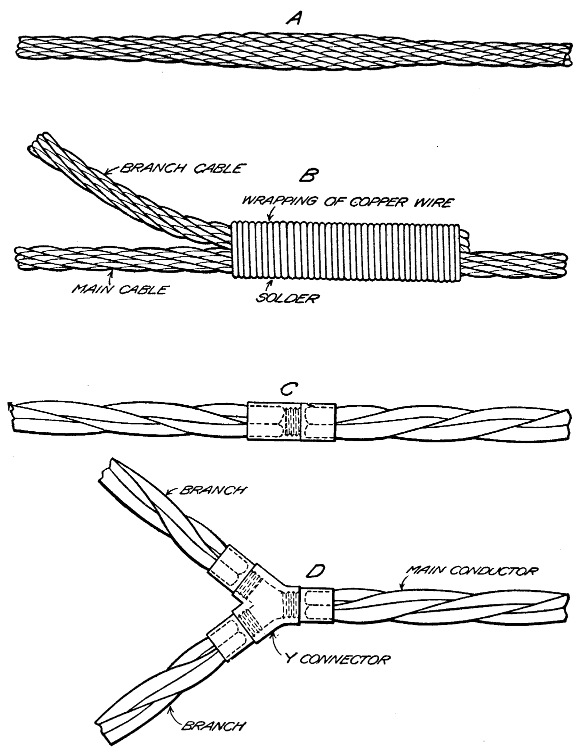

FIG. 6.—Types of conductor joints. (A) End to end splice of copper cable; (B) joint of branch to main cable; (C) end to end joint for star-section rod; (D) branch connections, star-section rod.

each of the several bidders. After the contract has been let and the work is under way, there should be inspections from time to time, particular attention being paid to the manner in which the "grounds" are being constructed. The contractor or his assistants, moreover, should be able to test out the electrical resistance of the grounds and thus determine their efficiency.

Repeating in a way what has been said before, it is well to emphasize that the installation of the best equipment available usually results in a future financial saving, even when the first cost is considerable. Besides, one has in the meantime a thoroughly reliable protection, subject to but slight deterioration and consequent need of repairs. However, even if the equipment is of the best, there should be *periodic inspection* and any *defects* should be *immediately repaired.* Efficient protection can not otherwise be maintained.

The methods to be followed in installing the various portions of the equipment are given in detail below.

Conductors.—Conductors of whatever kind should be installed in straight runs, except, of course, at necessary bends, where the changes in direction should be made in curves of large radii, one foot or more. For the best type of installation, bends or loops are required at the junctions on the roof of the main conductors with the aerials, and where the conductor passes over the edge of the roof on the way to ground, etc. (Fig. 5.) This construction is adopted to avoid side flashes of lightning.

Where end-to-end joints of the conductor become necessary, suitable conductors may be employed or soldered joints made, particularly if copper cables are used. When cables are used, however, they

should be run in single lengths as much as possible, so as to avoid unnecessary joints. Where branches with main conductor occur, the joints may also be soldered, or connectors used that preferably avoid right-angled connections. Several types of conductor joints are illustrated in figure 6, and a solderless connector for cable is shown in figure 9.

Conductor fasteners or supports.—Fasteners for carrying the conductor along the walls of a building generally should be spaced about 6 feet apart. In some cases, however, for instance, where the conductor passes over the edge of the roof, the spacing can not conform to the above rule. The one-piece screw fastener, No. 1 in figure 2, is very well adapted for most installations, being screwed directly into any wooden wall or roof, or used with expansion sockets, if the wall is made of brick, concrete, stone, or tile. After the fasteners have been screwed into place the conductor is inserted in the eye at the outer end and the two prongs brought tightly together about the conductor with a pair of pliers.

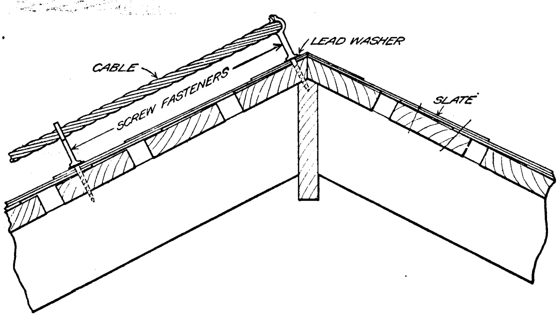

FIG. 7.—Conductor fasteners for use on shingle, metal, and slate roofs.

Fasteners Nos. 2 and 3 in figure 2 are designed to be secured in a brick, concrete, or tile wall while the building is being erected. Otherwise they are similar to fastener No. 1. As illustrated in figure 7, the screw fasteners are also readily adapted to shingle, metal, or slate roofs. Special fasteners are needed for a tile roof, but, since such roofs are not frequently found in rural districts, their construction has not been described. When screwing the fasteners to the roof renders a leak possible where the screw enters, provision should be made to make the holes water-tight by means of suitable washers or other devices.

Insulators.—Insulators, though formerly in general use, should not be employed. A good electrical connection with the wet roof and walls of a building facilities the harmless conduction of the discharge to ground.

Aerials.—The locations of the points and supports forming the aerials must be carefully chosen, and therefore sketch plans and elevations usually are required by the contractor. The manner in which the conductors are to be run and the grounds located should also be shown on such drawings. Figures 21, 22, 23, and 24 show several typical installations which should serve as guides to the

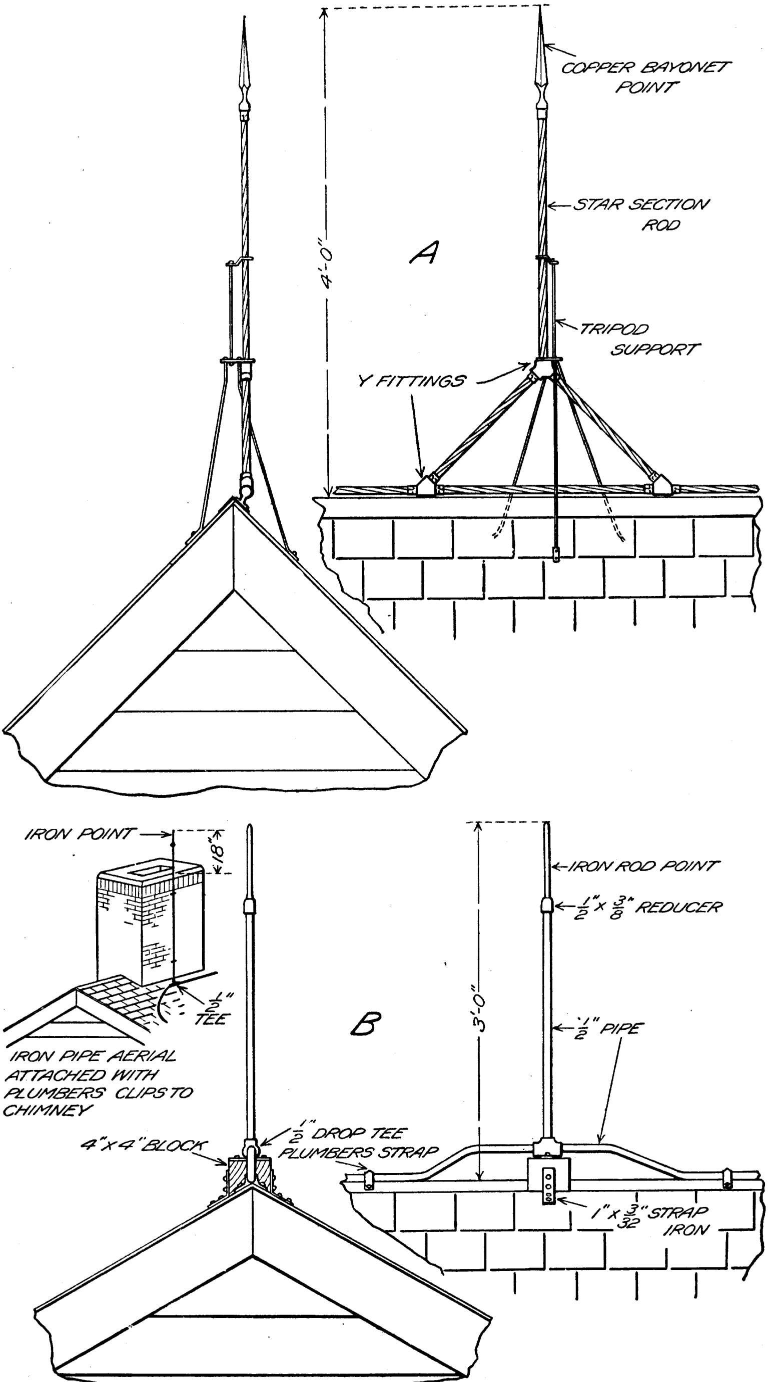

FIG. 8.—Aerials formed of (*A*), star-section rod; (*B*), iron pipe.

prospective purchaser of equipment. As a general rule, however, along ridges and flat roofs, the aerials should be spaced not more than 25 feet apart. On extensive flat roofs it would therefore be necessary to place aerials not only around the edge of the roof, but, in addition, at points more or less uniformly distributed about the area within the edge. Each elevated portion of the building, such as chimneys, peaks, towers, gable roofs, etc., ordinarily should be protected by one or more aerials.

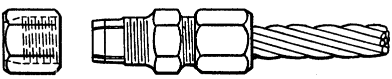

FIG. 9.—Solderless connector for cable conductors.

Steeples and towers.—Special care should be used in protecting church steeples or towers forming parts of buildings. Sometimes several aerials will be required, the number of the aerials depending upon the size and shape of the structure. Two conductors at least should be run from the aerials to separate grounds and the conductors cross connected to the balance of the system. (See fig. 24.)

Construction of aerials.—There are several methods of forming the aerials, differing principally in the kind of points and conductors used, and in the manner of forming the junctions of the points with the vertical conductors and of the vertical conductors to the main conductors. It is desirable, as before stated, that sharp bends or loops of the conductor be avoided, and, when copper or iron cables are used, the vertical cable can easily be bent into the horizontal in an arc of considerable radius, as shown in figure 3. This is not so easily accomplished with the star-section iron rod or other solid conductors, but the former may be screwed together with Y-connectors, as shown in figure 8 (a). In the simpler and cheaper forms of installation the avoidance of sharp bends is not considered, and T-shaped fittings are used, as illustrated in figure 8 (b). The junctions themselves may be either soldered or screw-jointed, or a solderless connector such as is shown in figure 9 used for cables. These connectors are believed to be thoroughly dependable, but the set-screw connectors that are quite frequently employed are not very reliable.

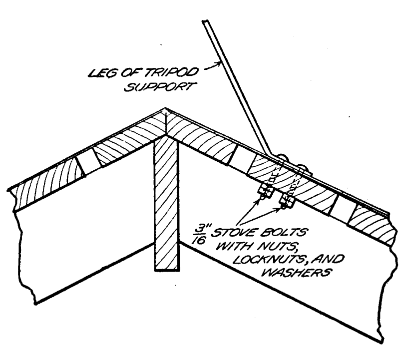

FIG. 10.—Method of fastening aerial support to roof.

Supports or braces for aerials.—The aerials should extend to a height of nearly 4 feet above ridges, gables, or flat roofs. A height of 18 inches above the top of an ordinary chimney is sufficient, as a rule, and short aerials may be provided for peaks, steeples, and other pointed parts of the building. (See fig. 10.)

Flagpoles.—Flagpoles are frequently injured or rendered useless when struck by lightning. A flagpole, however, can be almost completely protected from such damage by surmounting the pole with a metal fitting to form an aerial, and electrically grounding this aerial through a conductor, essentially as indicated in figure 11. If it were not for the possible fouling of the flag on the top of the pole when carried upward with the air currents, a sharp bayonet point might be used to surmount the pole. To avoid this difficulty, the use of a special bell-shaped casting, preferably made of bronze, is recommended, the upper portion of which should be sufficiently blunt to prevent the flag from catching.

The conductor should be attached to the pole with screw fasteners; also carefully soldered to the casting at the top of the pole, and grounded in the customary manner.

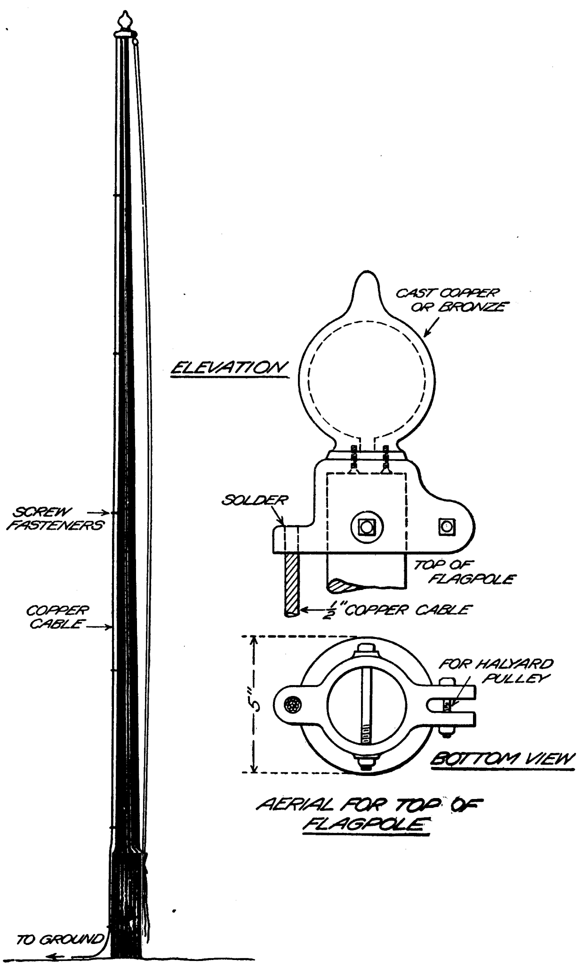

FIG. 11.—Protection of wooden flagpole.

Grounds.—The electrical connection of the lightning conductors on a building to permanently moist, and therefore conducting, earth, or what is technically termed "grounding," is the most important part of the work, for unless the "grounds" are carefully made the efficiency of the system is greatly reduced. Hence, every precaution and care should be exercised in constructing the grounds to the end that their electrical resistance may be as low as practicable. To secure the best results, several essentials are necessary: (1)

The soil in which the metal forming the ground is placed must be permanently moist; (2) the area of contact between the metal and the soil must be ample—better in excess than not enough; (3) the metal in the ground must be electrically connected to the conductor in as permanent a manner as possible; and (4) the corrosion of the metal used in the ground must be as slight as practicable.

To fulfill the first essential, the character of the soil in which the ground is to be made should be carefully determined before the type of ground is selected, due consideration being given to the dryness or wetness of the season, for good and reliable grounding requires electrical connection with that level at which the soil does not dry out during droughts and thus become nonconducting. Occasionally it will be impracticable to reach permanent moisture because of the rocky nature of the soil. In such case it is necessary to resort to the more expensive and often less efficient alternative of largely increasing the area of the ground by extending it horizontally as far beneath the surface as is practicable or economical. Occasionally a difficulty of this kind is met, more or less effectively, by burying a copper conductor in a trench extending entirely around the building and connecting this conductor to the rods on the building at two or more places. Another alternative is to increase the number of grounds.

The distribution of the grounds is also an important factor, and in general the distance between the several grounds should be equal or nearly so, but when it is necessary to make a connection to a water pipe or to avoid soil that will corrode the metals used, it is obvious that such a rule must be broken. Furthermore, the moisture conditions of the soil may be different at different places about the building, and the best locations for the grounds should be selected.

The conductors should be so arranged as to leave no stub or ungrounded ends.

Durable grounds can be realized only by using such metals as will not readily corrode. Copper, bronze, aluminum, and cast iron fulfill this condition, essentially in the order given. The life of galvanized wrought iron or steel when placed in the ground is relatively short as compared with copper or even cast iron. To avoid corrosion, especially of copper, bronze, and aluminum, earth connections should be located, if practicable, where there is very little or no seepage from manure piles or other refuse. Common salt is sometimes mixed with the earth to decrease the resistance of the ground connections. This advantage is temporary, however, lasting only until the salt is dissolved and carried away; moreover, salt tends to corrode the metal forming the ground.

As before remarked, two metals such as copper and iron should not be used together in the presence of moisture, since corrosion will

occur. Hence, this precaution is especially true as regards metals placed in the earth. If copper and iron are both used, the joint must be protected from moisture. Concrete may be used to effect this result, as shown in figure 12. When the joint is made at or near the surface of the ground, protection from both corrosion and injury may be secured, as shown, by embedding the jointed conductor in a block or cylinder of dense concrete about 6 inches in diameter and extending 6 inches or so above ground and about a foot below. Also, if the conductor along the side of the building immediately above the ground is in danger of mechanical injury, it should be protected by means of 1-inch galvanized-iron pipe about 8 feet long placed around the conductor, the lower end embedded in the above-mentioned concrete block and the pipe then filled to the top with a cement grouting.

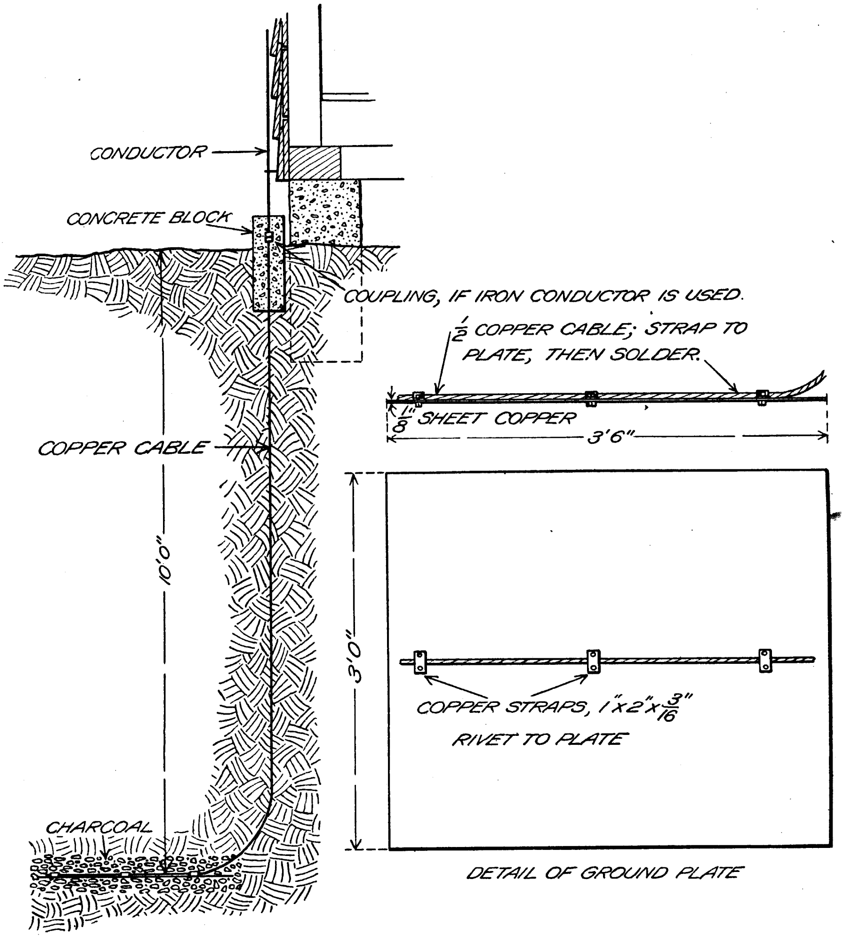

FIG. 12.—Copper-plate ground.

Another way to protect the conductor from injury is to surround it with a wooden box to the height desired. The top end of the box should be closed in to prevent the entry of dirt and moisture.

Details of construction of grounds.—Grounds may be constructed in accordance with any of the methods described and illustrated below, but those considered the most dependable are described first.

Copper-plate grounds.—Figure 12 shows a copper plate having an area of about 10 square feet to which the copper conductor is securely riveted and soldered. The thickness of the plate is one-eighth of an inch. Somewhat thinner metal might be used, but for long service the thickness mentioned is none too great. A ground plate of this character should be buried in earth where there is permanent moisture, with 4 or 5 inches of broken charcoal, pea size, above the plate and about the same thickness below. The charcoal absorbs water and therefore assists in maintaining a condition of the soil moist about the plate. Should iron conductors be used on the building, it is advisable to terminate them at the surface of the ground and use a copper conductor in the earth, but the joint of the copper to the iron must be protected from moisture, as stated above.

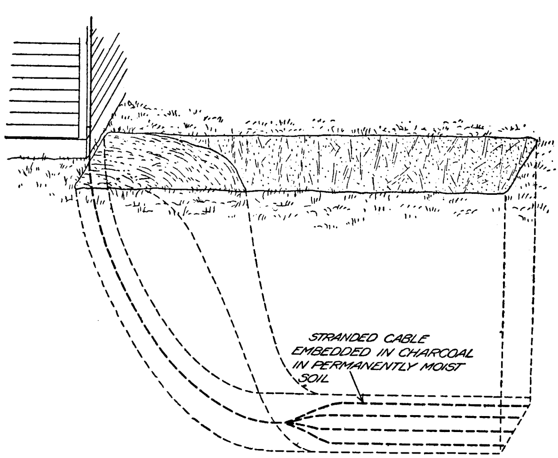

FIG. 13.—Stranded-cable ground.

Stranded-cable grounds.—When copper cable is used for a conductor, a very good ground may be made by burying the cable itself in the earth, as illustrated in figure 13. Dig a narrow trench extending to a distance of 15 feet or so away from the foot of the conductor to be grounded, or to a greater distance if the earth is rocky, and the trench must of necessity be shallow, and deep enough to insure permanent moisture, even in time of drought. The trench should slope downward somewhat away from the house end. Having dug the trench, separate the strands of the cable for a distance of 6 or 7 feet from the outer end, which end should reach to the end of the trench; or the cable should be stranded for a greater length if the trench is shallower and longer. Then embed the cable placed in the bottom of the trench in granulated charcoal about pea size, saturated with water, and fill in the earth and tamp thoroughly. Where the cable enters the

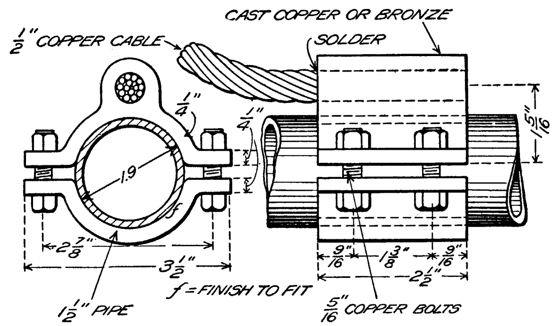

FIG. 14.—Clamp for water-pipe ground.

trench and passes to the bottom, the bend should be of large radius. It is not considered advisable to use stranded, galvanized-iron cable or rods in the ground on account of their susceptibility to corrosion. Should it be desired to lower the resistance of the ground somewhat, the area of metal in contact with the earth may be doubled by splicing a second short length of cable to the main cable and then stranding both of them.

Water-pipe grounds.—Wherever possible, grounds should be made by connecting the conductor to the metallic water piping, where it enters the building from an adjoining well, for instance. But it should first be definitely known that the pipe itself is well grounded, which is usually the case. A special fitting, preferably made of copper or bronze, is necessary for such a ground connection, such as is illustrated in figure 14. Similar fittings may be made for pipes of different sizes and kinds. This fitting is designed to clamp about the pipe, and the latter must therefore be carefully scraped and filed to thoroughly remove the rust and scale before the clamp is attached. There is a lug on the fitting to which the copper conductor is soldered. After the connections have been made, the clamp and the joint to the conductor should be painted with a heavy coat of hot asphaltum after first heating the parts with a blowtorch.

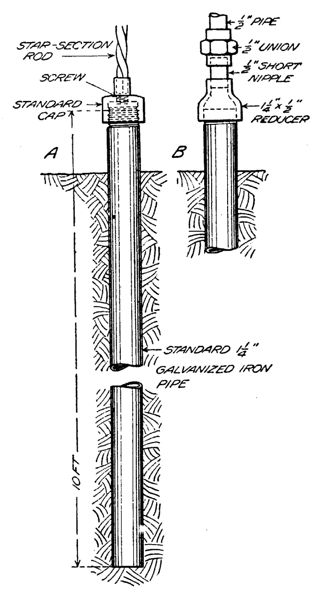

FIG. 15.—Galvanized-iron pipe grounds. *A*, Used with star-section conductor; *B*, used with iron-pipe conductor.

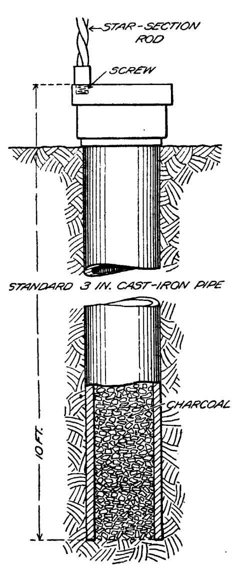

FIG. 16.—Cast-iron-pipe ground.

Pipe grounds.—Ordinary galvanized-iron pipe may be also utilized for grounds, but the life of

ordinary galvanized wrought iron or steel is relatively short when placed in the ground; hence such a ground should preferably be used for more or less temporary or moderate-priced installations. A special fitting is required to receive the conductor, if of star-section rod, which may be screwed to the upper end of the pipe as indicated in figure 15 (A). If ½-inch pipe is used for a conductor, the arrangement shown in figure 15 (B) will be necessary. It is also possible to use a length of cast-iron pipe for a ground as shown in figure 16. The pipe should preferably be placed under a down spout so that the water from the spout can flow downward outside and within the pipe, the inside lower part of which should be filled with granulated charcoal.

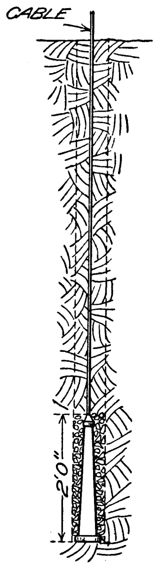

FIG. 17.—Ground cone.

Ground cones.—What are called ground cones are quite frequently employed by electric light, power, and telephone companies to ground their transmission lines, transformers, lightning arresters, etc. These cones may be purchased ready made, but the sizes available are small, and, excepting for their relative freedom from corrosion, they do not have any special advantages over iron-pipe grounds; in fact the latter probably have less resistance, as a rule. There are two types of cones on the market, one constructed of perforated sheet copper, the other made of carbon. The former is illustrated in figure 17, the cone proper being about 2 feet in length. To place one of the copper cones in use, the interior of the cone is first filled with pebbly charcoal, and then lowered into a posthole deep enough to provide permanent moisture about the cone.

Grounds of cast-iron rods.—A cast-iron rod, 1½ or 2 inches in diameter and 8 to 10 feet in length, may be used for a ground and would have the advantage of being very durable. It could be readily driven vertically into the earth if the soil is yielding and not rocky, or a hole could first be drilled in the earth, the diameter of which should be considerably less than that of the rod, so that the latter may be driven into this hole and make good electrical contact with the surrounding soil. The conductor should be soldered or screwed to a copper or brass lug driven into a hole drilled in the upper end of the rod. Figure 18 illustrates the attachment of a star-section conductor to a cast-iron rod. Other conductors can be treated in a similar manner.

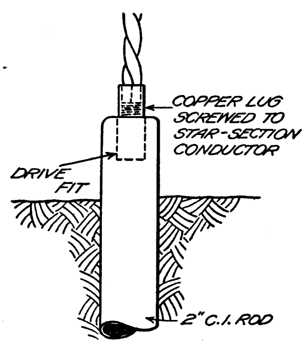

FIG. 18.—Connection of conductor to ground of cast-iron rod.

A cast-iron plate having an area of about 10 square feet and a thickness of three-eighths of an inch or so might be used for a ground similar to the one made with a copper plate, but such an iron plate, like the cast-iron rod, would be heavy and rather unwieldy and its cost considerable.

Grounds not to use.—The practice of making a small hole in the ground and inserting therein a portion of the same conductor used as a part of the equipment on the building should not be allowed. The area of contact of the metal with the earth is entirely insufficient to provide a ground of the necessary low resistance.

INTERCONNECTION AND GROUNDING OF THE METAL WORK ON BUILDING.

Exterior metal work.—All the exterior metal parts of the building of any considerable extent and size, such as roofs, gutters, down spouts, finials, etc., should be carefully cross connected to the lightning-rod system, unless the manner of installing the aerials or conductors has laready placed them in good electrical contact with the conductors. Usually it will be necessary to make permanent and dependable connections with copper or iron wire, soldering the joints. No. 6 B. & S. gauge wire is a satisfactory size for this work. Metal bodies of considerable lateral extent, such as the gutters and roofs, should be connected to the conductors from each end, or in the case of the roof from opposite corners at least. Metal work having considerable height should be connected at top and bottom to the nearest lightning conductors. Often the conductors are run alongside such bodies, and these cross connections can be very easily made. In the case of down spouts, if the gutters are cross connected and the joint to the down spout soldered, no cross connections of the latter to the conductors will be necessary at the upper ends. The lower ends must be grounded, either directly or by connection to near-by grounded conductors. The wires used to make the cross connections should be securely attached to the building in a neat and durable manner without being too conspicuous, and a fastener similar to the one illustrated in figure 2 (4), made of the same material as the wire, may be used for the purpose. A staple would also make a good fastener where the wire runs over a wooden surface of the building. It is obvious that the cross-connecting wires must often be protected from accidental injury.

Ungrounded metal roofs at best furnish very inadequate protection, and at times may even increase the probability of damage by fire because a charge of electricity induced in the roof may find its way to earth through the building.

Metal roofs may be so grounded by down spouts, etc., that the danger from lightning is minimized, but it would be unsafe to depend upon such a system. Hence a metal roof should at least be carefully

grounded from two places, or more if the roof is large. However, it is believed that better protection will be afforded by erecting aerials on the high parts of the building and along the ridges of the roof, in which case a thorough interconnection and grounding of the system will be secured by installing the usual network of conductors, and not depending upon the roof at all as a part of the system.

Interior metal work.—Pipes and other metal bodies extending for a considerable length parallel to the lightning conductor on the roof, or on the side of the building, should be connected to the conductor at one end and the other end grounded within the building or connected to another conductor on the exterior; provided the distance from the interior metal work to the conductor is 8 feet or less. The methods used in making such cross connections should be similar to those described in the preceding paragraph. Grounds within the building can frequently be made to the water piping, using a form of clamp similar to that illustrated in figure 14. Moderately small masses of metal do not require interconnection, excepting when they are less than 6 feet or so from the conductors outside, or the cross-connected metal work within the building. The interconnection of the metal work in a barn containing unbaled hay should be especially well done, since a small spark will ignite loose hay.

Grounding of windmill and other steel towers.—Towers used to support windmills ordinarily do not require any special protection against lightning, since they are constructed of steel and well grounded through the pump. Wooden water tanks placed upon steel towers should, however, be surmounted by an aerial connected to the metal work of the tower, and the latter well grounded by one of the methods above described. When the anchor posts of the tower are merely placed in the earth and not embedded in concrete, the grounding of the tower will usually be sufficient, depending upon the character of the soil, but the use of concrete necessitates separate grounding. The same treatment should be given steel flag, signal, and bell towers.

Lightning arresters.—All electric light, telephone, and power circuits entering a building from a pole line must be effectually grounded through suitable lightning arresters of approved types. The electric service and telephone companies usually look after this work, the telephone companies in particular, so that their instruments and apparatus will be effectively protected. The arresters for electric light and power circuits should be connected to the nearest ground provided for the lightning conductors of the building, or grounded separately if so desired, using copper cable or wire about one-fourth of an inch in diameter, the work to be done essentially as covered in the "Underwriters' rules."

Protection of trees.—If a building is more or less surrounded by high trees, these trees protect the building to quite an extent from light-

ning. This is especially true of those varieties of trees that are deep-rooted and therefore more susceptible to lightning strokes than others. Poplars, oaks, pines, elms, ash, etc., fall under this head. But the trees should be considered only as additional protection to the building, and the customary equipment should be provided for the latter. If the trees close to the building are valuable, and it is desired to protect them from lightning strokes, a few of the larger ones should be rodded. Place an aerial in the top of the tree, but not so high as to be insecure, and ground the aerial through a conductor secured to the trunk of the tree by screw fasteners. One of the grounds provided for the conductors on the building may be used, or a separate one constructed for the tree or group of trees. It is realized that the growth of trees will make the maintenance of the rodding thereon somewhat difficult, and in a good many instances its extension and partial renewal or repair every few years probably will be necessary. It is believed, however, that the additional protection of both trees and adjacent building secured makes the trouble and expense worth while.

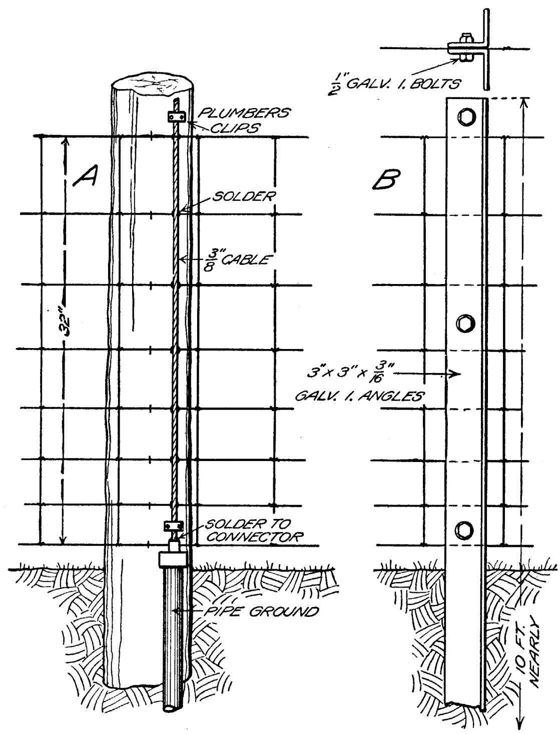

FIG. 19.—Grounding of wire fencing. (*A*) Fence with wooden posts; (*B*) metal posts.

Protection of live stock.—Live stock is quite frequently injured or killed by being in contact or close to an ungrounded wire fence struck by lightning at some place. To avoid this danger, the fence should be effectually grounded at intervals of about 150 feet, more or less, according to the conductivity or effectiveness of the several grounds. One of the cheaper forms of grounds described above should be used for such work. A suitable connection between ground and fence may be made with ¼-inch or ⅜-inch galvanized-iron wire or cable. The

conductor may be fastened to the fence post over the fence wire with plumber's clips and soldered if possible to each of the wires, essentially as shown in figure 19, A. Another possible method is illustrated in figure 19, B: Two galvanized-iron angles 3 by 3 inches by three-sixteenths inch being bolted together to form a fence post, with the wire fencing securely held between the angles. The angles should extend into the ground to a depth of 7 or 8 feet, or into permanently moist soil.

In addition to the grounding of the fence, at intervals that will usually correspond to the standard lengths in which the fencing is furnished, i. e., 20, 30, or 40 rods, gaps of several feet should be left in the wire fencing to prevent a lightning discharge from traveling any considerable distance along the fencing. These gaps should be filled in with wooden fencing (a nonconductor of electricity), in a solid and substantial manner.

There does not seem to be any need for grounding wire fencing attached to steel posts, especially if several of the posts are extra long and extend well into the ground.

Occasionally it will be necessary to protect shade trees under which the stock congregate. The method of rodding and grounding trees is given on page 22.

SPECIFICATIONS FOR INSTALLATION OF EQUIPMENT.

Three sets of specifications for the installation of different types of equipment are given below. These specifications naturally include and make practical application of portions of the preceding text, and form a basis to which may be added such further details as are necessary to suit the particular building to be protected.

COPPER-CABLE INSTALLATION.

(*a*) *Conductor.*—Tightly twisted copper cable of commercial purity will be used, approximately one-half of an inch in diameter, and composed of seven strands of four wires each. The cable will be run as directly as possible on the building, and sharp bends or loops will be avoided. Bends or loops of the cable where it passes over the edge of the roof on the way to ground will have large radii. Where the aerials meet the horizontal conductor the cable will be formed into an inverted Y, the vertical part of the aerial meeting the horizontal in an arc of about 16 inches radius.

Where end-to-end joints of the conductor become necessary, the strands at the cut ends will be interwoven for a distance of 5 or 6 inches and carefully soldered. The conductors will be run in single lengths where possible and unnecessary joints avoided. Where branches with the main conductor occur, the joints will be soldered, the branch cable meeting the main cable in an arc of large radius,

say 20 to 24 inches. These joints will be made by laying the cables side by side, binding the two together for several inches with copper wire, and then soldering carefully.

(*b*) *Cable fasteners and supports.*—Use gun-metal or copper screw fasteners of the type shown in figure 2 (1), or equally good. The fasteners will be placed about 6 feet apart as a rule and carefully screwed into the walls of the building.

Where the cable must be fastened to the concrete, stone, or brick walls, and chimneys, expansion screws must be used.

Should the screwing of the fasteners to the shingle roof render a leak possible where the screw enters, make the holes water-tight by means of lead washers.

No insulators will be used with the fasteners or for any part of the equipment.

(*c*) *Aerials.*—Details of the location of the aerials are shown on the sketches accompanying these specifications.

(*d*) *Points.*—Solid, copper-bayonet points without plating, of the type shown in figure 4 (1), will be used. The joints of the points to the vertical copper cables forming the aerials will be soldered.

(*e*) *Supports or braces for aerials.*—The tripod support shown in figure 3 will be used. Fasten the supports to the wooden roof with brass screws or with sherardized-iron through bolts when possible. When through bolts are used, provide a lock nut or upset the end of the bolt to prevent loss of nut.

(*f*) *Height of aerial.*—Install aerials 4 feet high above ridges, gables, and flat roofs; 18 inches above the tops of chimneys, peaks, and pointed parts of the building. (See sketch showing location of aerials.)

(*g*) *Grounds.*—Dig a narrow trench of sufficient depth to reach permanent moisture and to a distance of 15 feet or so away from the foot of the conductor to be grounded, or to a greater distance if the earth is rocky and the trench must be shallow. Separate the cable into its four strands for a distance of 6 or 7 feet from the outer end, which should reach to the end of the trench; or strand the cable for a greater length if the trench is shallower and longer. Embed the cable placed in the bottom of the trench in granulated charcoal, pea size, saturated with water, using about 5 inches of charcoal above the cable and the same thickness below. Fill in the earth and tamp thoroughly. Where the cable enters the trench and passes to the bottom, make a bend of large radius. (See fig. 13.)

Protect the cable from injury and corrosion where it enters the ground by surrounding it with a block of dense concrete, 6 inches or so in diameter, extending 6 inches above ground and a foot or so below. Also protect the cable from mechanical injury or loss by theft by surrounding it with a piece of 1-inch galvanized-iron pipe

about 8 feet long, the lower end embedded in the concrete block. When in place, fill the pipe to the top with a cement grouting.

(*h*) *Interconnection and grounding of metal work of building.*—Cross-connect the gutters and down spouts to the lightning conductors, using No. 6 B. & S. gauge copper wire with soldered joints, the gutters connected at each end and the down spouts at the lower ends. Solder the gutters to the down spouts.

Pipes and other metal work within the building, extending for a considerable distance parallel to the lightning conductors on the roof or the side of the building, will be cross connected to the nearest conductor at one end and the other end grounded or connected to another conductor on the exterior, provided the distance from the interior metal work to the conductor is 8 feet or less. Use No. 6 copper wire and solder the joints. Small masses of metal more than 6 feet from the nearest conductor outside or cross-connected metal work within will not be cross connected.

INSTALLATION OF IRON CONDUCTORS AND FITTINGS.

(*a*) *Conductor.*—Galvanized-steel, star-section rod with copper couplings will be used, three-fourths of an inch in diameter. Run the rod as directly as possible on the building, but avoid sharp bends or loops. Make the bends or loops of large radius where the conductor passes over the edge of the roof. Where the aerials meet the horizontal conductor, the conductor will be formed into an inverted Y as shown in figure 8 (a).

The stock length of the rod is 8 feet, each end provided with copper couplings. End-to-end joints are made by screwing the rods together. Where branches with the main conductor occur, Y connectors will be used so that easy bends may be formed with the laterals, as shown in figure 5.

(*b*) *Cable fasteners and supports.*—Use galvanized-iron screw fasteners with sherardized-iron screws or bolts. For details and further specifications see section (*b*) in "Copper-cable installation."

(*c*) *Aerials.*—Details of the location of the aerials are shown in the sketches accompanying these specifications.

(*d*) *Points.*—Solid, copper-bayonet points without plating, of the type shown in figure 4 (1), will be used. The point will be screw-jointed to the star-section rod forming the aerial.

(*e*) *Supports or braces for aerials.*—Use a galvanized-iron tripod support, fastening it to the roof with sherardized-iron screws, through bolts, or expansion screws, as the case requires. When through bolts are used, provide a lock nut, or upset the end of the bolt to prevent loss of the nut.

(*f*) *Height of aerial.*—See section (*f*) of "Copper-cable installation."

(*g*) *Grounds.*—Construct a copper-plate ground, as illustrated in figure 12, the area of the plate to be at least 10 square feet; its thickness one-eighth of an inch. Rivet and solder a ½-inch copper cable to the plate, the cable of sufficient length to extend to surface of ground and be screw-jointed to the star-section rod. Bury the ground plate in earth where there is permanent moisture, with about 5 inches of broken charcoal, pea size, above the plate and the same thickness below. Saturate charcoal with water, fill in hole, and tamp thoroughly.

Protect the conductor, including the joint of copper cable to galvanized-iron rod where it enters the ground, by surrounding it with a block of dense concrete, 6 inches or so in diameter, extending 6 inches above ground and a foot below.

(*h*) *Interconnection and grounding of metal work of buildings.*—Follow specifications, section (*h*) for "Copper-cable installation," excepting that No. 6 galvanized-iron telegraph wire, Birmingham wire gauge, and galvanized fittings and screws will be used instead of copper.

INEXPENSIVE EQUIPMENT.

(*a*) *Conductor.*—Use ½-inch galvanized-iron pipe for the conductor, extra heavy pipe if obtainable. Such pipe and the galvanized malleable-iron or cast-iron fittings therefor can be readily purchased locally in almost any portion of the United States, or ordered direct from supply houses located in the larger cities.

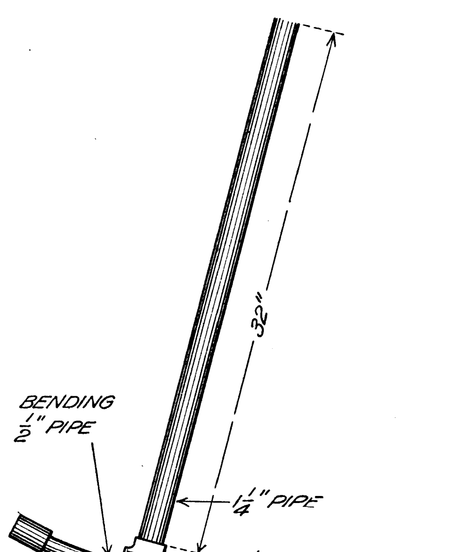

FIG. 20.—Pipe bender or hickey.

Run the pipe as directly as possible on the building, but avoid sharp bends or loops. To form the bends required, as for example where the pipe passes over the edge of the roof on the way to ground, the pipe should be bent into the proper shape by means of what is called a hickey. A simple pipe bender of this kind can be made with a 1¼-inch malleable-iron tee and a piece of 1¼-inch pipe about 30 inches long, screwed into the side outlet to form a handle, as indicated in figure 20. The conductor pipe will be screwed together with couplings, one of which should accompany each 10-foot length of pipe

as purchased. Where branches with the main conductor occur, as a the ends of the building on the roof, "Y-bend" fittings may be used and the branch pipes bent into arcs of large radius. Intermediate branches with the principal conductor should be made with crosses or tees.

(*b*) *Conductor fasteners and supports.*—Galvanized-iron pipe straps or plumber's clips are required for attaching the pipe to the building. Use iron screws for wood, and iron expansion screws for brick, tile, concrete, or stone walls.

The holes in the roof where screws enter should be made water-tight by means of suitable washers, lead if obtainable.

(*c*) *Aerials.*—The location of the aerials should be carefully chosen in advance of the actual work of construction, and indicated on simple sketch plans of the building.

The aerials will be constructed as shown in figure 8 (*b*) of standard galvanized-iron ½-inch pipe and fittings; the points of iron rod. Install aerials 3 feet high above ridges, gables, and flat roofs; 18 inches above the tops of chimneys, peaks, and pointed parts of building.

(*d*) *Grounds.*—Use pipe grounds of the type illustrated in figure 16, viz, a 10-foot length of 1-inch pipe, extra heavy if obtainable, driven into the ground until its upper end is about 4 inches above the surface of the ground. It may occasionally be necessary to first drill a hole in the earth and then drive the pipe into the hole thus formed. To the upper end of the ground pipe screw a ½-inch by 1-inch reducer and a short ½-inch nipple, and join into the conductor on the building by means of a common galvanized-iron union, all as shown in figure 12 (*b*).

(*e*) *Interconnection and grounding of metal work of building.*—Follow specifications, section (*h*), for "Copper-cable installation," excepting that No. 6 galvanized-iron telegraph wire, Birmingham wire gauge, and galvanized-iron fittings and iron screws will be used.

Special problems in lightning protection.—In the preceding pages no effort has been made to take up in detail the protection of elevators, oil tanks, tall chimneys, etc. The same general principles would apply, but these structures usually require special consideration. Letters of inquiry regarding lightning protection should be addressed to the United States Department of Agriculture Washington, D. C.

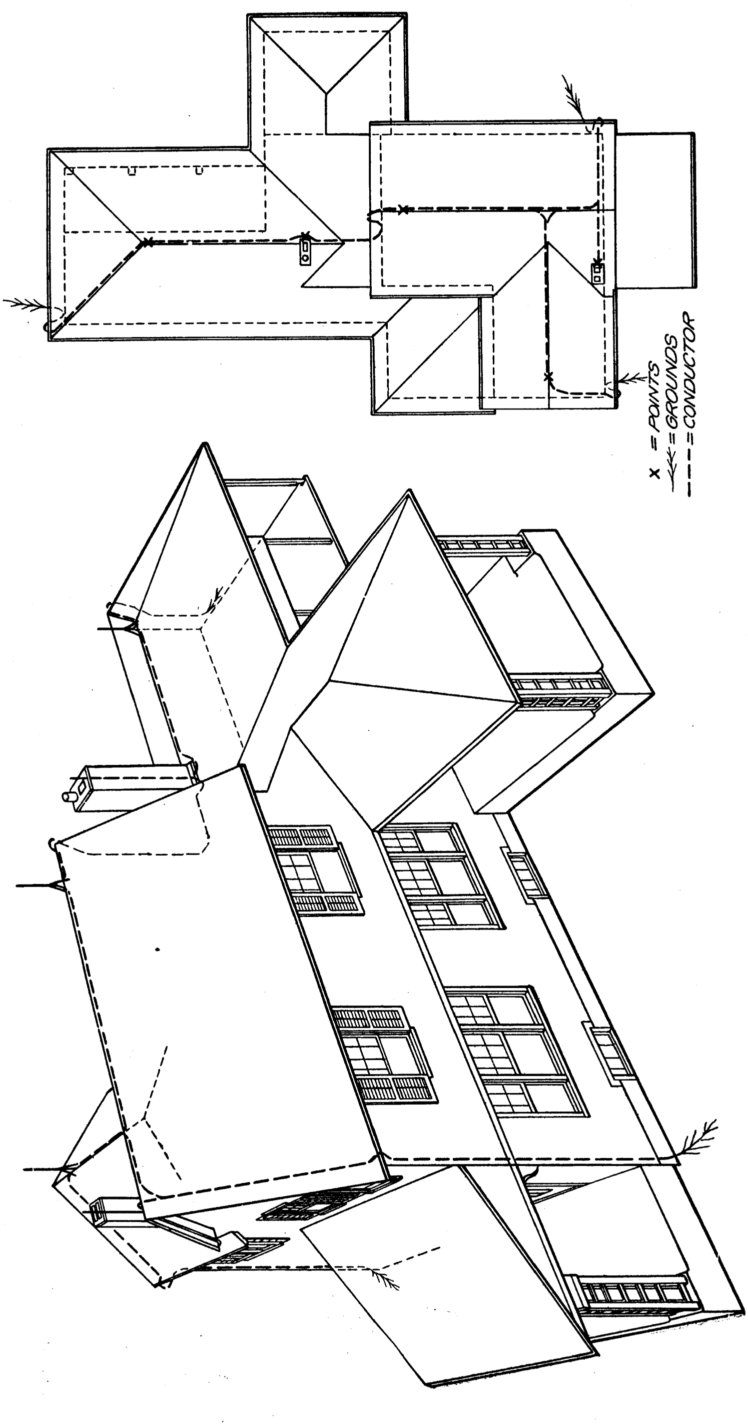

FIG. 21.—Protection of farmhouse against lightning. (The farmhouse illustrated was designed by the Office of Public Roads and Rural Engineering, Department of Agriculture.)

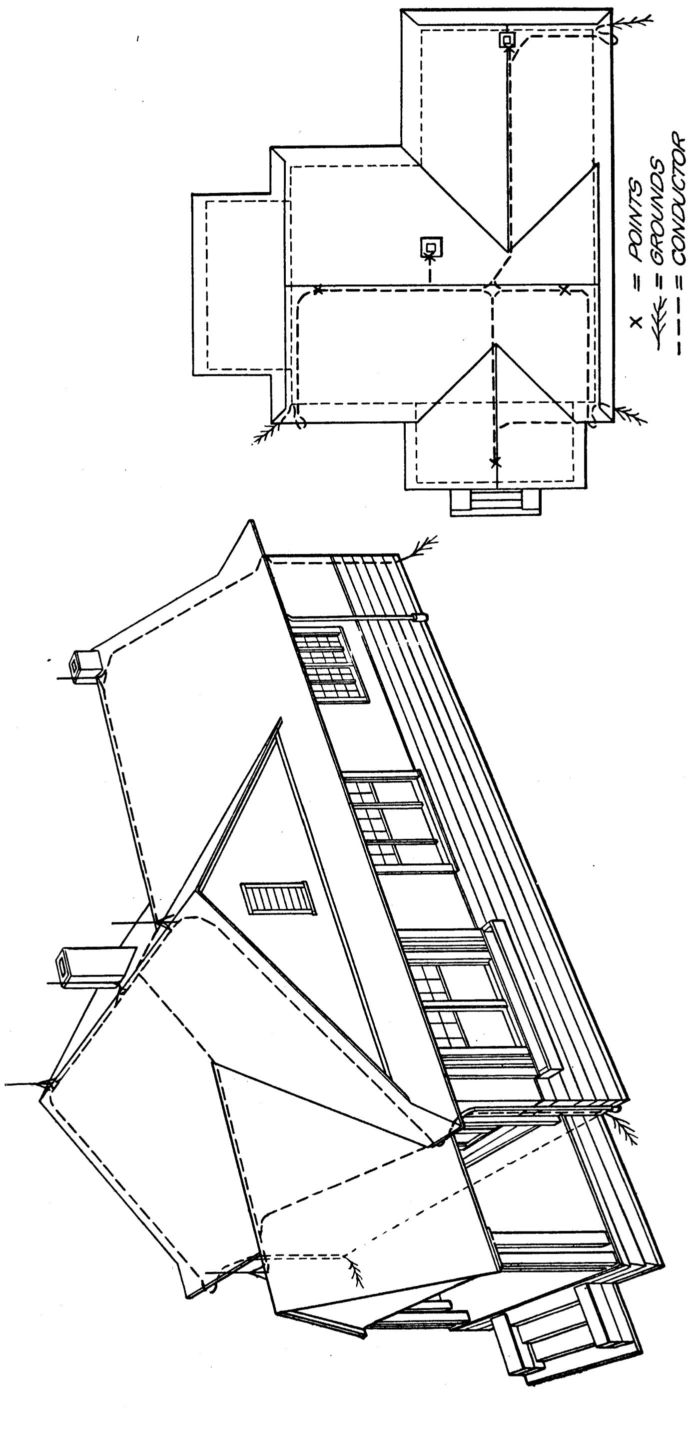

FIG. 22.—Protection of farmhouse against lightning. (The farmhouse illustrated was designed by the Office of Public Roads and Rural Engineering, Department of Agriculture.)

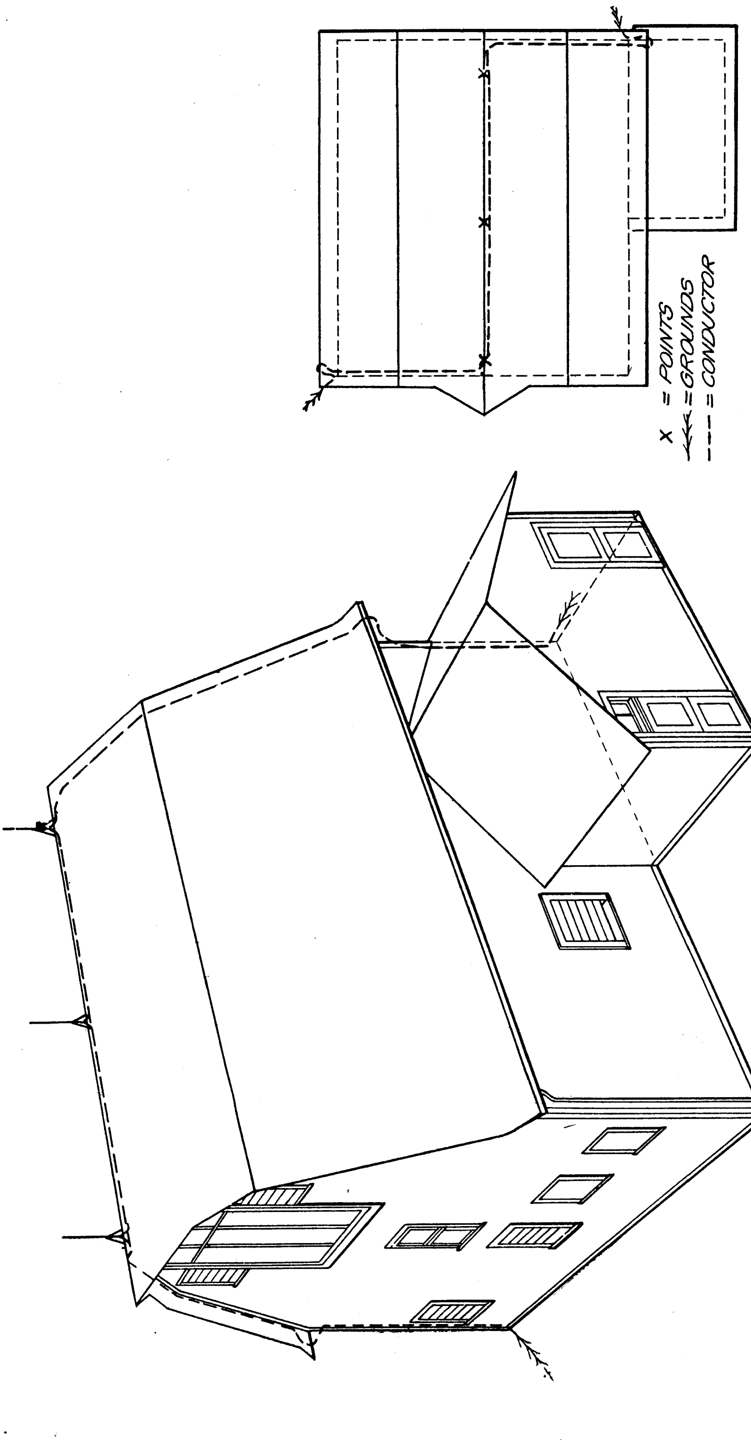

FIG. 23.—Protection of small general barn. (The barn illustrated was designed by the Office of Public Roads and Rural Engineering, Department of Agriculture.)

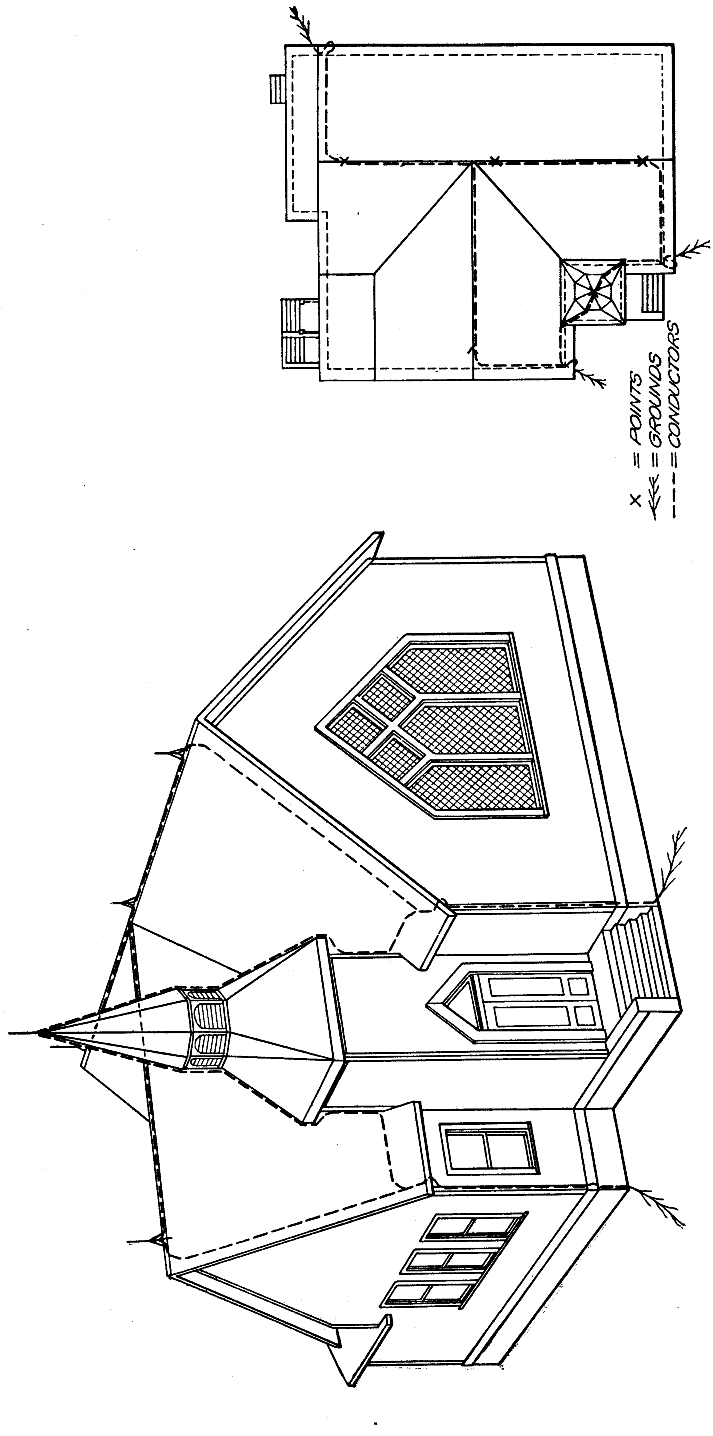

FIG. 24.—Protection of church building.